

CLAIMS

- 1 1. A spark plug for use in an internal combustion engine, comprising:
2 a shell having an axial bore;
3 an insulator having an axial bore and being at least partially located within said
4 shell axial bore;
5 a center electrode being at least partially located within said insulator axial bore
6 and having a thermally conductive core, a metal cladding, a main shank portion having a
7 diameter (H), and at least one radially reduced collar section having a diameter (J), said
8 collar section having an end face with a recess;
9 a noble metal tip having a diameter (K), an axial length (O), and a sparking
10 surface, and;
11 a ground electrode attached to said shell;
12 wherein said noble metal tip is located in said recess such that said noble metal tip
13 sparking surface extends beyond said collar section end face by a distance (L) and;
14 wherein:
15 $1.5\text{mm} \leq H \leq 3.5\text{mm}$;
16 $0.75\text{mm} \leq J \leq 1.75\text{mm}$;
17 $0.5\text{mm} \leq K \leq 0.9\text{mm}$;
18 $0.5\text{mm} \leq O \leq 4\text{mm}$; and
19 $0.1\text{mm} \leq L \leq 0.95\text{mm}$.
- 1 2. The spark plug of claim 1, wherein said noble metal tip is comprised of Ir
2 or an Ir-alloy.
- 1 3. The spark plug of claim 2, wherein said Ir-alloy is an Ir-Rh alloy having
2 Rh in the amount of 1-20%.
- 1 4. The spark plug of claim 1, wherein said center electrode metal cladding is
2 primarily comprised of Ni, Cr and Mn.

1 5. The spark plug of claim 1, wherein said center electrode main shank
2 portion has an axial length (F), wherein $10\text{mm} \leq F \leq 25\text{mm}$.

1 6. The spark plug of claim 1, wherein said thermally conductive core has an
2 axial length (G), wherein $10\text{mm} \leq G \leq 25\text{mm}$.

1 7. The spark plug of claim 1, wherein said noble metal tip includes an end
2 opposite said sparking surface, said opposite end being spaced from an end of said
3 thermally conductive core by a distance (N), wherein $2\text{mm} \leq N \leq 7\text{mm}$.

1 8. The spark plug of claim 1, wherein said noble metal tip sparking surface
2 and said ground electrode are separated by a spark gap (U), wherein $0.5\text{mm} \leq U \leq$
3 1.75mm .

1 9. The spark plug of claim 1, wherein said center electrode further includes
2 an additional radially reduced section that is coupled on one end to said main shank
3 portion via a first taper and is coupled on another end to said collar section via a second
4 taper, said second taper being larger than said first taper.

1 10. The spark plug of claim 1, wherein said ground electrode includes a
2 generally flat, noble metal pad for forming a spark gap with said noble metal tip sparking
3 surface.

1 11. The spark plug of claim 1, wherein said center electrode metal cladding
2 has a thermal conductivity of approximately 50 W/mK when the material is at a
3 temperature of around 1000°C .

1 12. A spark plug for use in an internal combustion engine, comprising:
2 a shell having an axial bore and a thread diameter (A);
3 an insulator having an axial bore and a nose portion with an axial length (C), said
4 insulator being located within said shell axial bore such that an outer surface of said nose
5 portion is spaced from an inner surface of said shell axial bore by a radial distance (B)
6 and said nose portion extends beyond said shell by a distance (D);

7 a center electrode being at least partially located within said insulator axial bore
8 and having a main shank portion and at least one radially reduced collar section, said
9 collar section having an end face with a recess;

10 a noble metal tip having a sparking surface, and;

11 a ground electrode attached to said shell;

12 wherein said noble metal tip is located in said recess such that said noble metal tip
13 sparking surface extends beyond said insulator by a distance (M) and;

14 wherein:

15 $10\text{mm} \leq A \leq 14\text{mm};$

16 $8\text{mm} \leq C \leq 20\text{mm};$

17 $0\text{mm} \leq B \leq 3\text{mm};$

18 $0\text{mm} \leq D \leq 6\text{mm};$ and

19 $1.5\text{mm} \leq M \leq 3.5\text{mm}.$

1 13. The spark plug of claim 12, wherein said noble metal tip is comprised of Ir
2 or an Ir-alloy.

1 14. The spark plug of claim 13, wherein said Ir-alloy is an Ir-Rh alloy having
2 Rh in the amount of 1-20%.

1 15. The spark plug of claim 12, wherein said center electrode includes a metal
2 cladding that is primarily comprised of Ni, Cr and Mn and exhibits a thermal
3 conductivity of approximately 50 W/mK when the material is at a temperature of around
4 1000°C.

1 16. The spark plug of claim 12, wherein said noble metal tip has a diameter
2 (K), wherein $0.5\text{mm} \leq K \leq 0.9\text{mm}.$

1 17. The spark plug of claim 12, wherein said noble metal tip has an axial
2 length (O), wherein $0.5\text{mm} \leq O \leq 4\text{mm}.$

1 18. The spark plug of claim 12, wherein said noble metal tip sparking surface
2 and said ground electrode are separated by a spark gap (U), wherein $0.5\text{mm} \leq U \leq$
3 1.75mm.

1 19. The spark plug of claim 12, wherein said ground electrode includes a
2 generally flat, noble metal pad for forming a spark gap with said noble metal tip sparking
3 surface.

1 20. A spark plug for use in an internal combustion engine, comprising:
2 a shell having an axial bore;
3 an insulator having an axial bore and being at least partially located within said
4 shell axial bore;
5 a center electrode being at least partially located within said insulator axial bore;
6 a noble metal tip having a diameter (K) and being attached to said center electrode, and;
7 a ground electrode having a thickness (P) in the axial direction, a width (Q) in the
8 radial direction, a side surface, and a noble metal pad with a diameter (S) that is greater
9 than diameter (K) of the noble metal tip, wherein said noble metal pad is a generally flat
10 pad attached to said side surface such that it forms a spark gap (U) with said noble metal
11 tip, and;
12 wherein:
13 $0.75\text{mm} \leq P \leq 2.25\text{mm};$
14 $2\text{mm} \leq Q \leq 4\text{mm};$ and
15 $0.5\text{mm} \leq S \leq 2\text{mm}.$

1 21. The spark plug of claim 20, wherein said noble metal pad is comprised of
2 Pt or a Pt-alloy.

1 22. The spark plug of claim 21, wherein said Pt-alloy consists essentially of
2 either Pt-Ni or Pt-W.

1 23. The spark plug of claim 21, wherein said ground electrode further includes
2 a thermally conductive core and a metal cladding, said core is spaced from a free end of
3 said ground electrode by a distance (R), wherein $1\text{mm} \leq R \leq 5\text{mm}$.

1 24. The spark plug of claim 23, wherein said thermally conductive core is not
2 located directly underneath said noble metal pad.

1 25. The spark plug of claim 20, wherein $0.5\text{mm} \leq U \leq 1.75\text{mm}$.

1 26. The spark plug of claim 20, wherein said ground electrode further includes
2 a free end that is tapered.

1 27. The spark plug of claim 20, wherein attachment of said noble metal pad to
2 said side surface causes the electrode material directly underneath said noble metal pad to
3 become more dense, but does not cause any protrusion around the periphery of said pad.

1 28. The spark plug of claim 27, wherein said noble metal pad extends beyond
2 said side surface by a distance (T), wherein $0\text{mm} \leq T \leq 0.5\text{mm}$.

1 29. The spark plug of claim 20, wherein said noble metal pad is attached to
2 said side surface according to a process that involves both resistance and laser welding.

1 30. A spark plug for use in an internal combustion engine, comprising:
2 a shell having an axial bore and an outer thread diameter (A);
3 an insulator having an axial bore with an interior bore diameter (E) and being
4 at least partially located within said shell axial bore;
5 a center electrode being at least partially located within said insulator axial bore
6 and having a main shank portion with a diameter (H), a first radially reduced portion
7 having a diameter (I), and a collar section having an end face with a recess;
8 a noble metal tip located in said recess, and;
9 a ground electrode attached to said shell;

10 wherein:

11 A is about 14mm;

12 $2.5\text{mm} \leq E \leq 3\text{mm};$
13 $2.5\text{mm} \leq H \leq 3\text{mm};$ and
14 $2.25\text{mm} \leq I \leq 3\text{mm}.$

1 31. The spark plug of claim 30, wherein said noble metal tip is comprised of Ir
2 or an Ir-alloy.

1 32. The spark plug of claim 31, wherein said Ir-alloy is an Ir-Rh alloy having
2 Rh in the amount of 1-20%.

1 33. The spark plug of claim 30, wherein said noble metal tip has a diameter
2 (K), wherein $0.5\text{mm} \leq K \leq 0.9\text{mm}.$

1 34. The spark plug of claim 30, wherein said noble metal tip has an axial
2 length (O), wherein $0.5\text{mm} \leq O \leq 4\text{mm}.$

1 35. The spark plug of claim 30, wherein said ground electrode includes a
2 generally flat, noble metal pad for forming a spark gap with said noble metal tip sparking
3 surface.

1 36. The spark plug of claim 35, wherein said noble metal tip and said noble
2 metal pad are separated by a spark gap (U), wherein $0.5\text{mm} \leq U \leq 1.75\text{mm}.$

1 37. A spark plug for use in an internal combustion engine, comprising:
2 a shell having an axial bore and an outer thread diameter (A);
3 an insulator having an axial bore with an interior bore diameter (E) and being at
4 least partially located within said shell axial bore;
5 a center electrode being at least partially located within said insulator axial bore
6 and having a main shank portion with a diameter (H), a first radially reduced portion
7 having a diameter (I), and a collar section having an end face with a recess;
8 a noble metal tip located in said recess, and;
9 a ground electrode attached to said shell;

10 wherein:

11 A is about 12mm;

12 $2\text{mm} \leq E \leq 2.5\text{mm};$
13 $2\text{mm} \leq H \leq 2.5\text{mm};$ and
14 $1.75\text{mm} \leq I \leq 2.25\text{mm}.$

1 38. The spark plug of claim 37, wherein said noble metal tip is comprised of Ir
2 or an Ir-alloy.

1 39. The spark plug of claim 38, wherein said Ir-alloy is an Ir-Rh alloy having
2 Rh in the amount of 1-20%.

1 40. The spark plug of claim 37, wherein said noble metal tip has a diameter
2 (K), wherein $0.5\text{mm} \leq K \leq 0.9\text{mm}.$

1 41. The spark plug of claim 37, wherein said noble metal tip has an axial
2 length (O), wherein $0.5\text{mm} \leq O \leq 4\text{mm}.$

1 42. The spark plug of claim 37, wherein said ground electrode includes a
2 generally flat, noble metal pad for forming a spark gap with said noble metal tip sparking
3 surface.

1 43. The spark plug of claim 42, wherein said noble metal tip and said noble
2 metal pad are separated by a spark gap (U), wherein $0.5\text{mm} \leq U \leq 1.75\text{mm}.$